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H. H. Bennett, Chief

EROSION OF TOPSOIL REDUCES PRODUCTIVITY

By

J. H. Stallings

Research Specialist

Soil Conservation Service-Research

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SUMMARY

The potential increase in agricultural output resulting from the vast improvements made in the science of crop production in past years has been offset in large measure by the damage to the soil resulting from the action of wind and water in the erosion process. The sifting and sorting action of wind and water separates the organic matter and silt and clay fractions from the soil mass and carries them from the field. The parts lost contain most of the essential plant nutrients and other life-giving substances.

Large quantities of these valuable materials may be removed from a field by the erosion process without entailing a corresponding loss of soil volume from the surface of the land. In extreme cases the soil is removed bodily. These life-giving substances usually constitute the first portion of the soil to be removed by erosion. The removal of the soil and the accompanying organic matter and plant nutrients by either wind or water erosion results in lowering the production potential of the soil.

INTRODUCTION

Vast improvements have been made in the science of crop production during the last 60 to 75 years. Inorganic fertilizing materials have been and are being constantly improved both as to the content and availability of nutrients and the physical properties of the product. Rates of fertilizer application have been increased enormously in many areas and the number of farmers using fertilizer has increased many times over. Better adapted and higher-yielding varieties of crops have been developed through plant breeding and other work in the plant sciences. Improved methods of crop and soil management have been made available. Better materials and equipment for control of insect pests and diseases have been developed.

TABLE 1.--National average annual acre yield of cotton and corn by 10-year periods beginning with 1869 and ending with 1948

Period	Average annual acre yield	
	Cotton lint Pounds	Corn Bushels
1869-78	171.6	25.9
1879-88	172.5	25.8
1889-98	191.3	26.0
1899-08	187.7	27.4
1909-18	183.3	25.8
1919-28	162.6	27.0
1929-38	198.0	23.0
1939-48	256.0 ¹	33.0

¹Average for the 9-year period ending with 1947.

ACRE YIELDS HAVE NOT KEPT PACE WITH ADVANCES IN THE SCIENCE OF PRODUCTION

These and other related developments would have brought about large increases in per-acre crop production if the fertility of the soil had been maintained. If the productivity of the Nation's soils that prevailed when the soils were first put under the plow had been maintained at or near its former level, the average per-acre crop yields should have shown steady and consistent increases estimated at as much as 40 to 60 percent during the last 50 years for most of our principal crops. Actually, the increase of some crops has been much less than this. The national Average acre-yield of corn and cotton, for example, increased but very little up to 1938 as shown in table 1. Since then there has been some increase in the average acre-yields of both these crops.

The recent increases coincide with a combination of agricultural advances which were greatly stimulated as a result of the war effort--increased spread of conservation farming and, for corn, the advent of hybrid varieties.

Cotton acreage was greatly curtailed in the old cotton-growing area and expanded into new territory in the Southwest. In the Southeast, better lands were selected for cotton production, the rate of fertilization was stepped up appreciably along with a tremendous expansion in the planting of legume cover-crops and in other improved soil-conserving practices. Perhaps the advent of hybrid corn was the greatest single factor contributing to the recent increase in corn yield. As with cotton, the amount of fertilizer used on the crop during this period was greatly increased and efforts toward the adoption of better farming practices in general were intensified.

A more or less steady decline in soil fertility has largely, sometimes entirely, offset the many advances and improvements made along the line of agricultural production. This is illustrated by the average per-acre yields of eight of the more important crops grown in Michigan during the period 1871 to 1940 (table 2).

TABLE 2.--Average annual yields of 8 crops in Michigan for 70 years by 10-year periods, in bushels per acre¹

Crop	1871-80	1891-90	1891-1900	1901-10	1911-20	1921-30	1931-40
Wheat	15.0	14.9	14.0	15.6	16.9	19.5	20.4
Corn	33.4	27.5	30.0	32.2	33.3	30.4	32.6
Oats	21.9	31.9	29.7	31.3	34.0	31.0	31.0
Rye	14.4	12.2	13.6	15.0	14.4	12.9	12.3
Buckwheat	16.1	12.9	14.2	14.4	14.1	12.0	14.2
Barley	22.9	22.7	22.0	25.0	25.2	23.9	24.8
Potatoes	86.0	73.0	80.0	89.0	90.0	97.0	97.0
Tame hay ²	1.21	1.22	1.21	1.33	1.28	1.12	1.27

¹Data from J. M. Turke, Department of Soil Science, Michigan State College.

²Yield expressed in tons per acre.

With the exception of wheat and potatoes, there was no appreciable trend of increase in the yield of any of these crops in the 70-year period, whereas an actual decline occurred in some of them.

LARGE QUANTITIES OF PLANT NUTRIENTS ARE REMOVED

Analyses of old cropped or eroded Willamette Valley soils in Oregon, when compared with native sod land, have shown definite reductions in plant nutrients and an increase in soil acidity (27)¹. The decreases in nitrogen, calcium and sulphur were as much as 50 percent, and the lime requirement increased about one-half to three-fourths ton an acre. It is estimated that the soils of the Willamette Valley sustain a net annual loss of 29,000 tons of nitrogen and a heavy loss of potassium, sulphur, calcium and magnesium, ranging from 2,500 to 106,000 tons annually. The annual loss of nutrients is from 2 to 17 times the amounts returned to the land, depending on the kind of nutrient.

The immensity of plant nutrient losses due to erosion is indicated by the amount of silt and nutrients carried in the water of the Tennessee River system. For example, on the assumption that this silt came entirely from the row crop, idle and other land subject to severe erosion, it has been estimated that the loss from each acre of such land during 1939 would average 5.2 tons of silt, 84.6 pounds of CaO, 97.9 pounds of MgO, 212.2 pounds of K₂O, 13.0 pounds of P₂O₅, and 23.8 pounds of nitrogen (10). Calculated on the basis of the total acreage of the watershed, the average acre losses of the three bases, as oxides, carried in solution were 167.0 pounds of calcium, 31.7 pounds of magnesium and 7.1 pounds of potassium.

The estimated losses from the land in the entire Mississippi River basin during the same period averaged 1.9 tons of silt, 43.6 pounds of CaO, 53.8 pounds of MgO, 55.6 pounds of K₂O, 5.08 pounds of P₂O₅, and 6.64 pounds of nitrogen per acre of open farmland. On the basis of the total acreage in the watershed the average acre losses were .6 ton of silt, 13.6 pounds of CaO, 16.9 pounds of MgO, 17.4 pounds of K₂O, 1.59 pounds of P₂O₅, and 2.03 pounds of nitrogen.

The amount of mineral nutrients contained in the drainage waters of the Tennessee River watershed varies with the nature of the stratum from which the waters flow. The water draining the limestone areas contains the greatest amount of total mineral matter and that from the sandstone areas the least. However, the drainage waters from the sandstone areas contain more than twice as much potassium as the drainage waters from the limestone areas (20). The amount of phosphorus in the drainage waters varied with the amount contained in the soils from which the water flowed. The waters draining the highly phosphatic soils of the blue grass area contained the greatest amount of phosphorus. The greatest amount of nitrate-nitrogen was found in drainage waters containing the largest amount of soluble phosphorus, thus indicating the close relation between soluble-phosphorus and nitrate-nitrogen content.

The amounts of nutrients carried annually in solution by the Mississippi and Ohio Rivers are shown in table 3 (20).

TABLE 3.--Amounts of plant nutrients carried in solution annually in the Ohio and Mississippi Rivers

Element	Ohio River ¹	Mississippi River ²
	<u>Tons</u>	<u>Tons</u>
Phosphorus	17,199	62,188
Sodium	119,446	630,720
Potassium	396,521	1,626,312
Calcium	6,752,222	22,446,379
Magnesium	1,629,319	5,179,788
Sulphur	2,229,544	6,732,936

¹At confluence with the Mississippi River.

²At Baton Rouge, La.

In addition to the mineral nutrients carried by the Mississippi River in solution, this stream carried in suspension 7,469 million cubic feet of soil annually.

¹ Figures in parenthesis refer to literature cited.



Figure 1.-- Severe water erosion removes the body of the soil from large areas.

Leaching removes large quantities of plant nutrients from the soil, and much larger amounts of nutrients are lost by this means from certain productive soils than from less productive ones (33). For example, Muscatine soil in Illinois lost 311.4 pounds of calcium per acre in 3 years and 8 months, or a little more than 27 times as much as Cowden soil which lost 11.5 pounds in the same time. The nitrogen loss during this period was 280.9 pounds per acre on Muscatine soil as compared with 14.2 for Cisne soil. Magnesium losses were not as high as those of nitrogen or calcium but showed the same general relation to soil types. There was only a slight loss of potash from any of the 10 soil types studied. The greatest loss was 5.0 pounds from Muscatine soil and the smallest was 1.8 pounds from Osceola soil.

EROSION DEPLETES SOIL FERTILITY

Soil erosion has played, and continues to play, a major role in impairing the productive capacity of the nation's soils. Organic matter, nitrogen, and the clay and silt fractions of the soil, which contain the life-producing nutrients, are removed by the erosive action of wind and water. The selecting and sorting action of these agencies separates the lighter materials from the coarser and heavier sand particles and carries them off, leaving the more inert and less productive material behind. If erosion is severe, the body of the soil itself is carried off (figs. 1 and 2).

Depletion of fertility in crop land is brought about by the combined action of many factors (23). Annual cropping removes large amounts of nutrient materials. Soluble constituents are lost through leaching processes. Organic-matter decomposition as a result of microbial activity proceeds at a rapid rate in cultivated soils. In addition to these and many other factors, the process of erosion is now recognized as one of the most serious forces in the rapid depletion of fertility and productivity of cultivated lands.

Much experimental evidence is available to show the extent to which erosion carries away the life-producing part of the soil--the part that contains the nitrogen and mineral plant nutrients essential to plant growth.

WIND REMOVES THE MOST PRODUCTIVE PART OF THE SOIL

The light-weight particles of soil are the important ones in the great new dry-land winter-wheat belt of the Southern High Plains (9). It was the loss of such particles during the dust storms of the 1930's that opened the way for serious inroads on the fertility reserves of the soils in this area (fig. 3). The first soil drift of 1933 to lodge in a fence row on the Panhandle Experiment Station at Goodwell, Okla. contained 24.6 percent of organic matter. The drifted soil had been separated by wind from the surface of topsoil averaging less than 2 percent organic matter. Removal of the rich topsoil lowered crop yields 4.5 times as fast as did later removals of surface and subsoil material.

Each shift of soil by the wind serves to remove more plant nutrients. After the soil is moved a large number of times, the remaining soil that forms the dunes is mainly sand, regardless of the original texture (7). In Oklahoma, after the heavy wind storms of the early 1930's, the organic matter-nitrogen ratio in the cropped soil was 22.47, that in the virgin soil 23.30; and the average of the drifts was 24.44. As a result of cropping and wind erosion, the organic matter in the cultivated soils was decreased 18 percent and the nitrogen was decreased 15 percent. Very little difference occurred in the nitrogen and organic matter content of the cropped and virgin subsurface soils.

The wind tends to change the soil texture through removal of the silt fraction and may deplete the total fertility of the soil by sifting out the lighter and more fertile portion and carrying it away (11). Samples of dust collected in Oklahoma during the dust storms of 1930 contained on the average 62.5 percent silt and 14.3 percent sand. The original soil, Richfield silt loam, contained 42 percent silt and 35.4 percent sand, whereas the drift soil contained 58.2 percent sand and only 15 percent silt. The effect of the sorting action of the wind on the silt and sand content of the resulting products as compared with that of the original Richfield silt loam is illustrated in figure 4.

The dust contained 1.77 times as much combustible matter as the field soil and 1.47 times as much as the drift soil. The total nitrogen content of the dust was 2.15 times that of field soil and 1.88 times that of drift soil. The dust contained 1.95 times as much phosphorus as the field soil and 2.04 times as much as the drift soil, and contained 1.99 times as much base-exchange calcium as the field soil.



Figure 2.--Effect of wind erosion. The organic matter, silt and clay particles in the soil were blown away, leaving the coarser sand to form drifts. The soil beyond the drifts was blown out to plow depth.

Samples of dust laid down on snow and ice in Iowa by a dust storm originating in the Texas-Oklahoma Panhandle early in 1937 were collected and compared with samples taken from a small dune formed by the same wind disturbance at Dalhart, Texas (4). The dust contained roughly 10 times as much organic matter, 9 times as much nitrogen, 19 times as much phosphoric acid, and about one and one-half times as much potash as the dune material. Analyses indicated a similar sorting effect with respect to removal of both soil particles and chemical constituents. The unaffected grass-covered soil contained 79.2 percent coarse materials (total sands) as compared with no sand in the dust, and 19.6 percent of fine material (silt and clay) as compared with 97 percent in the dust. The dust contained more than three times as much organic matter and nitrogen, respectively, as the virgin soil; nearly five times as much phosphoric acid; and one and one-quarter times as much potash.

Samples of the dust originating in the 1937 Panhandle storm and deposited at Hays, Kans. and Clarinda, Iowa were compared with samples of soil of unplowed grassland and with dune sand collected near Dalhart, Texas (4). The results of the analysis of the samples are shown in table 4.

TABLE 4.--Organic matter and partial chemical content of soil of unplowed grassland, dune sand and dust

Element	Unplowed grassland, near Dalhart, Tex.	Dune sand, Dalhart, Texas	Dust.	
			Hays, Kans.	Clarinda, Ia.
	Percent	Percent	Percent	Percent
CaO	0.34	0.31	3.15	1.98
K ₂ O	2.05	1.77	2.46	2.58
P ₂ O ₅	0.04	trace	0.14	0.19
Nitrogen	0.06	0.02	0.20	0.19
Organic matter	1.06	0.33	3.34	3.35

The data show that the original unplowed soil was much higher in essential plant nutrients and organic matter than the dune sand but much lower in these materials than the dust collected at Hays and Clarinda.

WATER SORTS OUT THE MOST FERTILE SOIL CONSTITUENTS

Much fertile material in the soil is lost through erosion (fig. 5). Material eroded from Collington sandy loam in New Jersey from June 12, 1938 to December 31, 1941 contained four times as much organic matter, 1.5 times as much phosphorus, 1.4 times as much potassium and 2.3 times as much calcium as there was in the soil before erosion occurred (24). The loss per acre due to erosion was 1,149 pounds of organic matter, 67 pounds of nitrogen, 154 pounds of P₂O₅, 575 pounds of K₂O and 141 pounds of CaO. There were more than 3.5 times as many particles averaging less than 50 microns in diameter in the eroded material as in the surface soil from which the material came. The eroded material contained 58 percent of materials of this size-class as compared with slightly less than 16 percent in the original soil.

The material eroded from Dunmore silt loam cropped to corn was 16 percent richer in total nitrogen and 11 percent richer in phosphorus than the original soil (28). Water-soluble phosphorus in water extracts of eroded material from corn land contained six to eight times as much organic phosphorus as was contained in extracts of the parent soil.

A study of 48 depleted soils and the corresponding virgin soils in Michigan showed that the virgin soil had a greater rate of solubility, as measured by the freezing point method with moisture content somewhat above saturation (21). A decrease in rate of solubility is one of the important changes a soil undergoes in passing from a virgin to a more or less depleted condition. This is important since most crop plants feed primarily in the surface or plowed stratum of the soil and the solubility of subsoils is usually very low compared with that of the surface soils.

The total amount of salts in runoff water from soil erosion plots at Columbia, Mo. during the year May 1, 1924 to April 30, 1925 ranged from 166.8 pounds per acre for a plot in wheat and clover to 380.1 pounds per acre for a plot that was spaded 4 inches deep in the spring and fallowed throughout the season (8). Calcium and sulphur were lost in larger amounts than any of the other elements determined. Although the loss of potassium was rather small, the loss of this element from several plots was much greater than the amount that would ordinarily be applied in commercial fertilizer.



Figure 3.-- Fertility removal in action. The dust carried aloft in the wind erosion process contains the most fertile part of the soil.

Soil type and cover had a marked effect on both the amounts and concentrations of the solubles lost in runoff at Geneva, N. Y. during the 13-month period, March, 1938 to March, 1939, inclusive (5). These effects appeared to be related to variations in soluble concentrations at the soil surface and to the relative rates of infiltration and runoff. The concentrations tended to be higher in the summer months. The proportional losses of the separate soluble constituents in runoff varied considerably. Although losses of solubles reported in runoff were small, an analysis of the factors that produce variability in runoff losses indicates that appreciable losses may be incurred where poor soil management practices are employed.

ORGANIC MATTER, NITROGEN AND FINE MATERIALS USUALLY THE FIRST TO BE REMOVED

The annual nitrogen losses from land in Missouri planted to intertilled crops on slopes averaging 200 feet in length have been found to range from 3.8 percent of the total amount contained in the surface 7 inches of soil for a 2-percent slope to 11.1 percent for a 12-percent slope (38). The annual losses on 2-percent slopes ranged from 3.8 percent for slopes averaging 200 feet in length to 10.9 percent for slopes that averaged 1,200 feet in length. Corresponding losses on a 12-percent slope were 11.1 percent for the 200-foot slope and 18.1 percent for the 1,200-foot slope.

The loss of nitrogen declined with the introduction of sod-producing crops into the rotation and disappeared altogether on well-sodded meadows or pastures.

Numerous reported depletions of organic matter, formerly attributed to oxidation, may have resulted from erosion (30). Depletion of organic matter appeared to be a linear function of erosion. The calculated organic matter percentage of the soil dropped 0.002 percent at both Clarinda, Ia. and Bethany, Mo. for each ton of soil lost by erosion. The amount of organic matter removed by erosion is greater than the corresponding depletion indicated by analyses of the plot soils; consequently, the original organic matter level does not compensate for losses of "reserve" organic matter.

It was estimated that erosion removed the organic matter 18 times as fast as did oxidation from a fallow plot on which the greatest erosion occurred, and that to have maintained the organic matter at the original level it would have been necessary to apply as much as 9.2 tons of clover hay annually.

Marked and significant differences in erodibility occurred in New York under a uniform treatment, following treatments which permitted great differences in the rate of erosion (12). The calculated percentage of organic matter in the soil to plow depth was found to have dropped about 0.002 percent for each ton of soil lost by erosion.

The losses of organic matter caused by erosion in New York vary both in amount and character. They tend to be high in proportion to the total amount of soil and the proportion of fines that are lost (31).

The depth of topsoil has been found to be less important than the selective removal of certain parts of the soil by the raindrop splash process (18). An 11-year study on four soil types at Ithaca, N. Y. showed that soil was lost at rates varying from a trace to 138 tons per acre. Only 29 percent of the remaining plow layer passed through a 2-millimeter screen, whereas approximately 95 percent of the soil that was washed off passed through such a screen.

RUNOFF GREATER ON ERODED SOILS

Studies in Wisconsin showed that a severely eroded soil was not only lower in organic matter and nitrogen, but lost more rainfall by runoff than did less eroded soils (14). Severely eroded Fayette silt loam had only one-third as much organic matter and one-half as much nitrogen as moderately eroded Fayette silt loam. The severely eroded soil, when planted to grain, lost through runoff about twice as much rainfall during the growing season as moderately eroded soil. A severely eroded soil planted to corn allowed 1.3 times as much runoff as moderately eroded soil, and severely eroded soil planted to hay allowed 2.8 times as much runoff as moderately eroded soil.

Under severe erosion, eroded materials tend to approximate the composition of the uneroded soil, and the process is in effect "removal layer by layer" (31). With more moderate runoff there is a selective removal of the finer particles. Small local deposits of sand on the soil surface may be swept off by later rains, but if frequent cultivation constantly presents a fresh surface to the sorting action of running water, a continued removal of the finer particles may be expected.

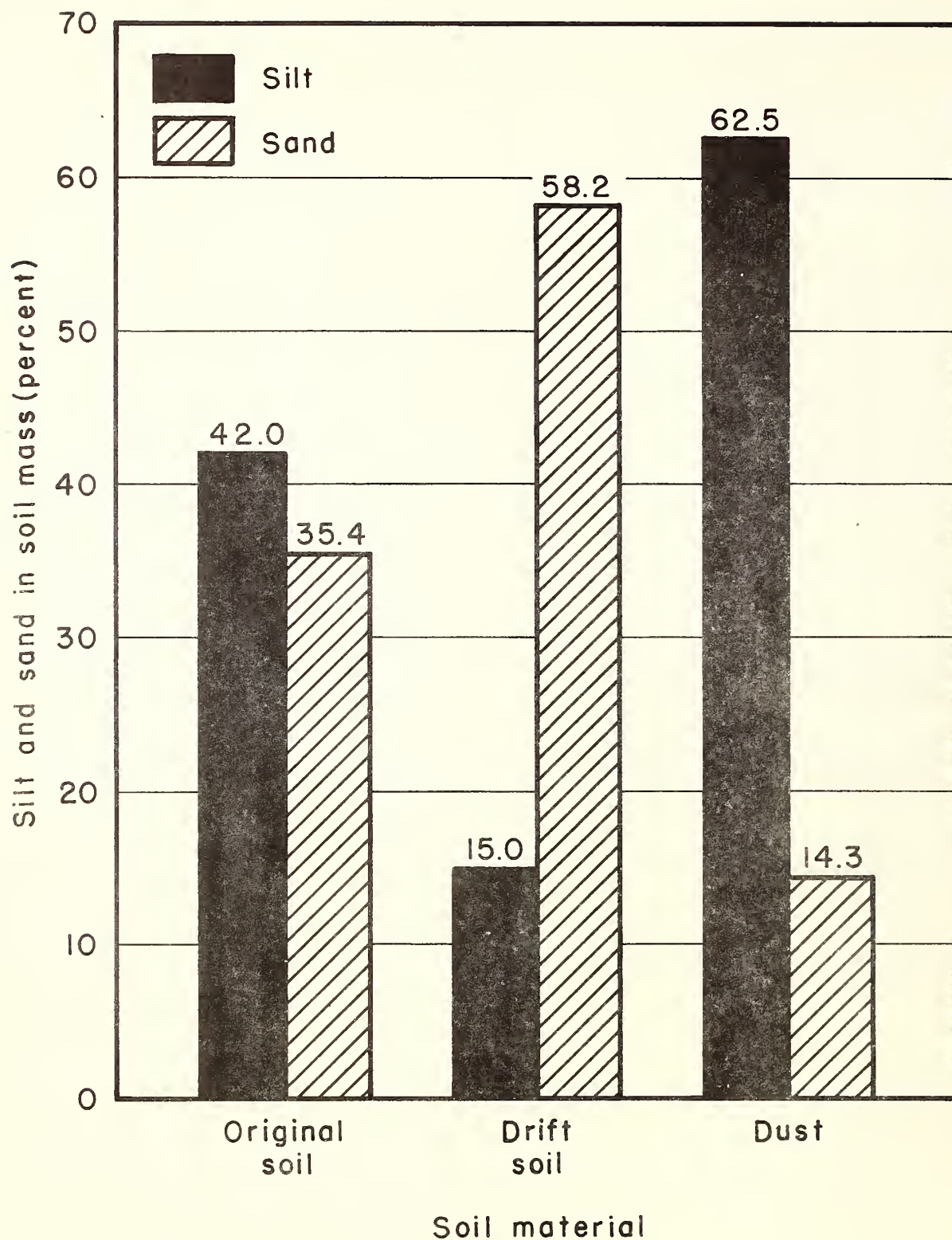


Figure 4.-- Changes in silt and sand content of Richfield silt loam caused by the sifting and sorting action of wind in the erosion process.



Figure 5.-- Fertility erosion in a cultivated field. Splashing rains have separated the organic matter, silt and clay particles from the sand and carried them away, leaving the washed sand in the furrows (light-colored deposits between the rows at the upper end of the field).

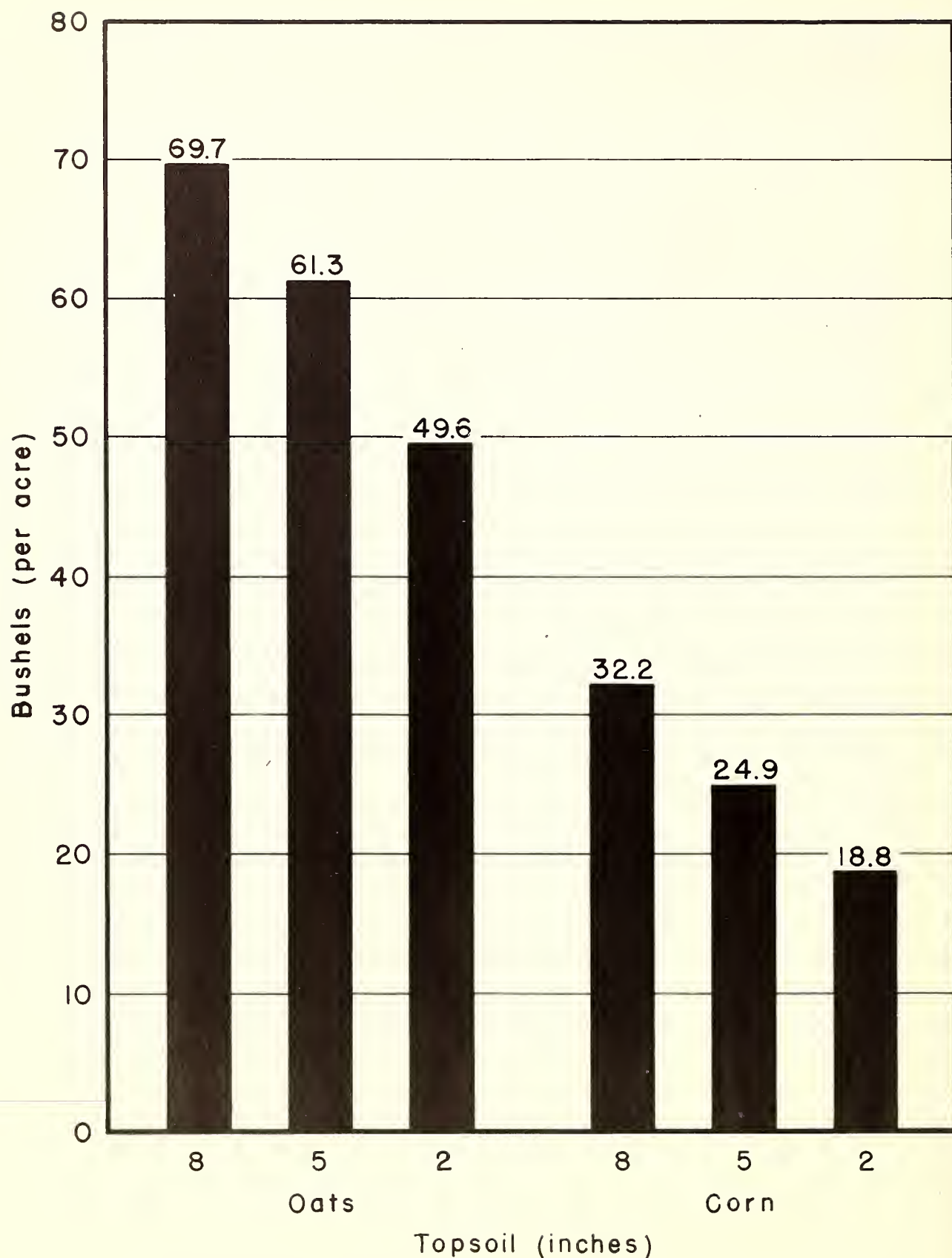


Figure 6.-- Effect of past erosion on the yield of corn and oats on Cecil soil, Watkinsville, Georgia. Average annual yield per acre for the period 1943-47.

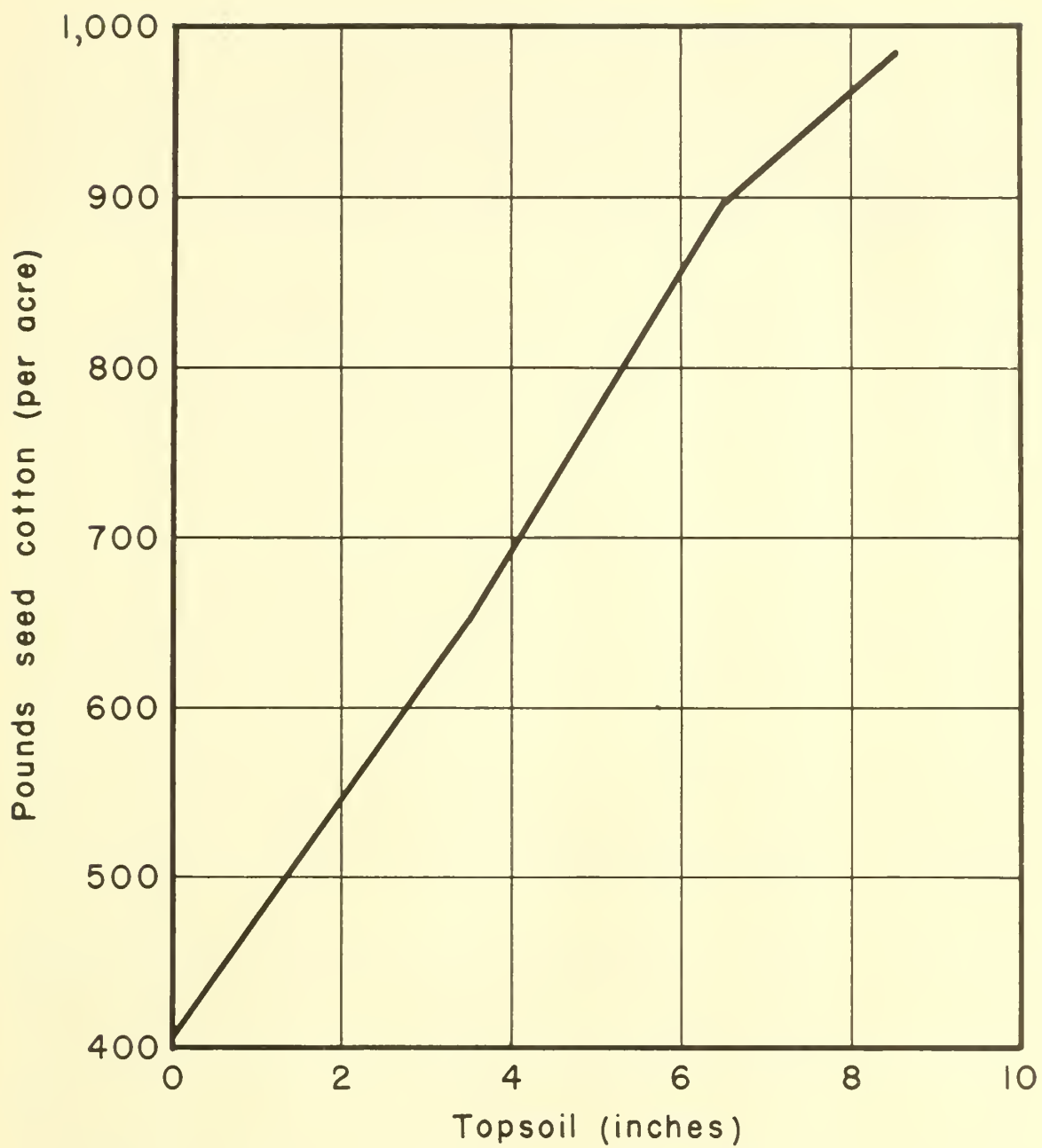


Figure 7.— Correlation between depth of topsoil and cotton yield on Cecil soil at Watkinsville, Georgia.

DEPTH OF SOIL AN IMPORTANT FACTOR IN CROP YIELDS

A study was conducted with corn in Iowa in 1936 and with corn and oats in 1937 to determine the relation of soil type to corn and oat yields (22). As a result it was found that yields vary not only with soil types but also, and more importantly, with depth of soil on the same soil type. Corn yield increased from 31 to 53 bushels per acre on Tama silt loam in 1936 with increase in depth of surface soil from 0 to 12 inches. An even more impressive correlation of yield and soil depth was obtained in 1937, both with corn and oats. Corn yield in 1937 increased from 47 to 88 bushels per acre as the depth of topsoil increased from 0-2 to 12 inches. The average acre-yields of corn on Tama silt loam, as related to depth of topsoil during the 2-year period 1936-37, and of oats in 1937, are shown in table 5.

TABLE 5.--Effect of depth of topsoil on yield of corn and oats on Tama silt loam

Depth of surface soil, in inches	Corn				Oats	
	1936		1937		1937	
	No. of samples	Average yield	No. of samples	Average yield	No. of samples	Average yield
		Bu. per acre		Bu. per acre		Bu. per acre
0-2	4	31	7	47	0	
3-4	8	28	10	69	2	52
5-6	30	39	19	77	7	61
7-8	39	49	33	82	11	70
9-10	23	50	19	88	4	72
11-12	12	50	25	82	4	70
12	11	53	19	88	2	64

These data indicate that the depth of topsoil, particularly from 7 inches, has a pronounced effect on corn yield on Tama silt loam. The results with corn grown on this soil were substantiated by data obtained on Clarion loam and Clarion fine sandy loam during 1937. Clarion loam which, after erosion, had less than 7 inches of topsoil remaining, produced 51 bushels of corn per acre, whereas the same type of soil with over 7 inches of topsoil produced 67 bushels. Corresponding yields for Clarion fine sandy loam were 39 bushels per acre with less than 7 inches of topsoil and 54 with more than 7 inches of topsoil remaining.

A close correlation existed between the yield of corn, cotton and oats and the depth of topsoil under certain cropping practices on three A-horizon depths in the 2- to 8-inch range depths of Cecil soil in Georgia during a 5-year period (16). The yield of cotton was 615.9 pounds per acre at the 2-inch depth, 889.1 pounds at the 5-inch depth and 1,019.6 pounds at the 8-inch depth. The yields of corn were 18.8, 24.9 and 32.2 bushels per acre for the 2-, 5-, and 8-inch depths, respectively. The yield of oats was 49.6 bushels per acre for the 2-inch depth, 61.3 bushels for the 5-inch depth, and 69.7 bushels for the 8-inch depth.

These yields represent an average of a number of crop rotations. The data show an average annual decline of 64 pounds of seed cotton per acre for each inch of topsoil lost from the 2-inch to the 8-inch depth. The yield of corn declined an average of 2.2 bushels per acre for each inch of topsoil lost and the yield of oats declined 3.3 bushels per acre for each inch of topsoil lost within the 2- to 8-inch depth range of topsoil. The yields of corn and oats as correlated with the depth of topsoil are shown graphically in figure 6.

The yield of cotton grown continuously during a 5-year period at Athens, Ga. ranged from 405 pounds of seed cotton per acre where there was no topsoil to 985 pounds for the 8.5-inch depth. The yield for the 6.5-inch depth of topsoil was 894 pounds and the estimated yield at the 3.5-inch depth was 650 pounds. This gave practically a straight-line average increment of 70 pounds of seed cotton per acre for each inch of topsoil depth. This straight-line relationship is illustrated in figure 7.

A remarkably close association of yield with soil depth and rotation system was demonstrated by this study. Cotton grown in the same rotation pattern on land in capability classes

II and III yielded 1,217 and 1,213 pounds of seed cotton per acre, respectively, on the two series of plots, each of which averaged exactly 7.6 inches in topsoil depth.

Yields of corn, oats, wheat and second-year hay were obtained over a 2-year period on various depths of topsoil for one residual soil group and three glacial soil groups in the Muskingum River watershed in Ohio (3). These yields represent the average of approximately 200 wheat plots selected at random on 24 different farms, 35 hay plots on 8 different farms, 74 oat plots on 12 different farms, and 81 corn plots on 10 different farms. The fields selected for study had received uniform treatment, and the crop history of each field during the 3- or 4-year period prior to sampling was known. Areas were selected within the fields which had different depths of topsoil, and yields were obtained for these areas.

The data indicate that a reduction in crop yield can be expected as erosion reduces the depth of the topsoil. This reduction occurs whether a relatively high or low scale of productivity is maintained. The reductions in yields per acre which can be anticipated for each inch of topsoil removed by erosion are reported in table 6.

TABLE 6.--Average annual reduction in acre yields of corn, oats, wheat and hay that can be anticipated for each inch of topsoil lost on glacial and residual soils, Muskingum River Watershed, Ohio

Crop		Glacial soils	Residual soils
Corn	bushels	1.50	3.16
Oats	do	1.61	2.31
Wheat	do	1.54	1.55
Hay	tons	0.101	0.113

A pronounced relationship between depth of surface soil and grape production was observed on Chenango soil in Pennsylvania (1). Production varied with depth of surface soil, depth being the factor which determined the amount of organic matter, nitrogen, and available moisture contained in the surface layer. By allowing an additional amount of soil per vine, more of these essential factors for plant growth apparently became available to each plant, and production was thus increased. These findings are summarized in table 7.

TABLE 7.--Relation between depth of surface soil, pruning weight and yield of grape vines - average for 1946-47

Pruning weight or yield	Depth of surface soil in inches					
	5.0-6.0	6.1-7.0	7.1-8.0	8.1-9.0	9.1-10.0	10.1-11.0
Pruning weight						
pounds per vine	1.0	1.8	1.8	2.2	2.3	2.6
Yield do	7.9	11.3	11.4	12.5	12.5	14.1
Yield tons per acre	2.37	3.39	3.42	3.75	3.75	4.23

Studies were conducted on three watersheds at Coshocton, Ohio in 1941 to determine the relation of the depth of topsoil to corn yields. Yield measurements made on 4-, 5-, 6-, 7-, 8-, and 9-inch depths of topsoil on each watershed, expressed in bushels per acre, were 33.7, 41.2, 46.4, 59.9, 51.1 and 59.5, respectively. These yield data are shown graphically in figure 8.

Erosion has lowered crop yields throughout the country generally, and has resulted in abandonment of both large and small areas. Some of the abandoned land may have been too shallow for cultivation at the time it was broken out, but much of it was reduced in depth by erosion to the point where it became too shallow for cultivation. Once reduced to a depth insufficient for adequate water storage for crop growth, such lands are virtually lost to the growing of cultivated crops except under irrigation, regardless of the inherent productivity of the soil material.

Information was obtained on 989 soil observations and wheat samples taken from the Wild Horse and Rock Creek sample areas in Oregon in 1939, 1940 and 1941 (34).

On the Wild Horse area the average yield of wheat on soils 48 inches or more in depth was 46 bushels per acre as compared with 22 bushels on soils less than 24 inches in depth. The yield was 43 bushels per acre where the topsoil was 14 to 18 inches in depth as compared with 13 bushels where the topsoil was less than 6 inches in depth. The results on the Rock Creek area

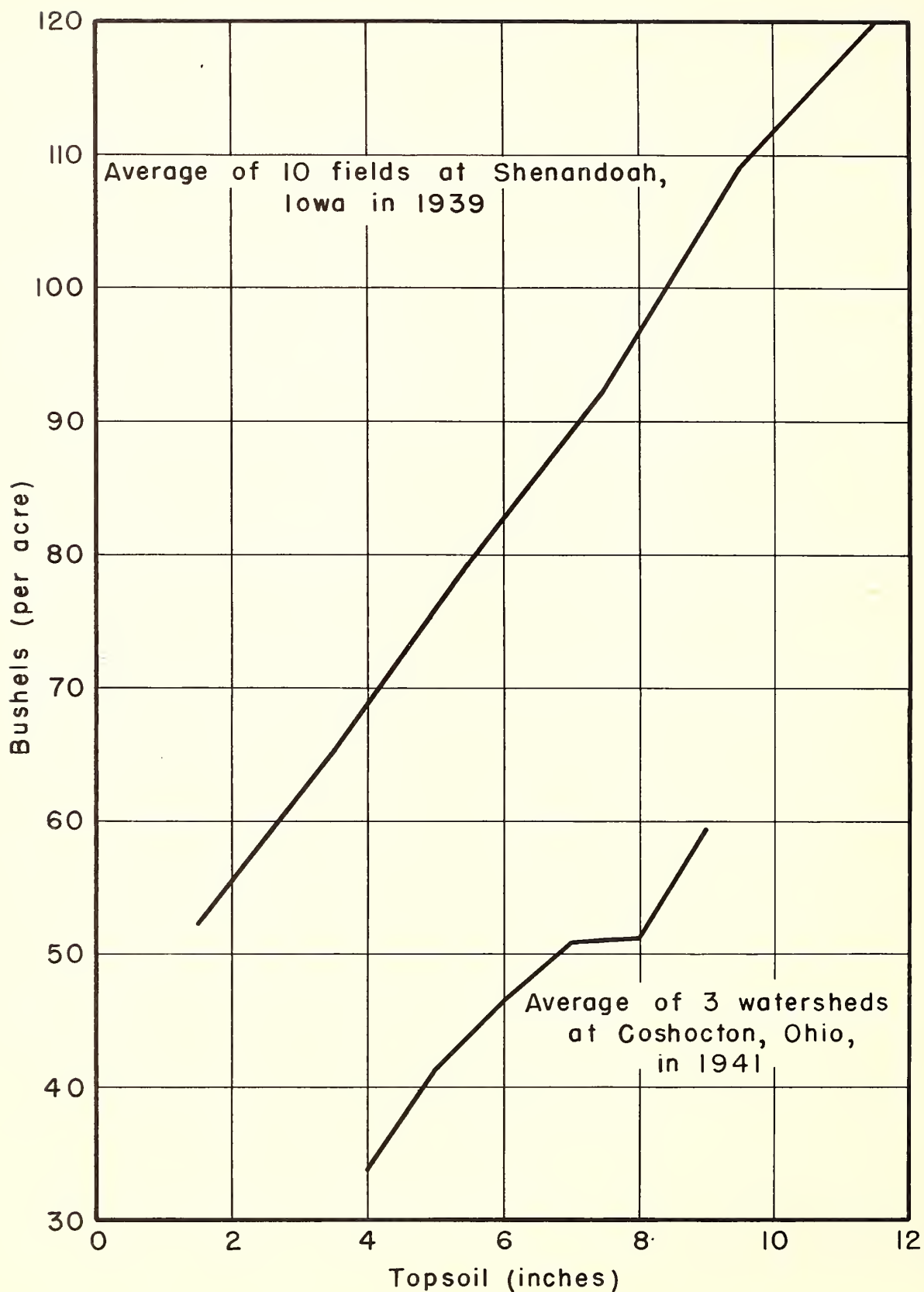


Figure 8. --Corn yields expressed in bushels per acre for different depths of topsoil in Iowa and Ohio.

show that yields of 27 bushels were reduced to 20 bushels as the total soil depth changed from more than 48 inches to less than 24 inches, and that yields of 31 bushels declined to 21 bushels with a change from 15 to less than 10 inches in depth of topsoil.

The loss of an inch of topsoil caused a reduction of 0.9 bushels per acre in the yield of wheat in the Wild Horse area, and 0.8 bushels in the Rock Creek area. The change in yield due to erosion was most pronounced on shallow soils, amounting to as much as 1.7 bushels per inch where the topsoil was less than 6 inches deep.

The corn yield for 1943 on non-desurfaced Austin clay at Temple, Texas was 27.6 bushels per acre, whereas that for desurfaced soil, representing the marly C horizon, was but 16.4 bushels (36). The desurfaced plot had been cropped to row crops during the period 1932-43 with a green manure crop that was turned under each year. In spite of this treatment, the corn yield on the desurfaced plot was but 59.4 percent of the yield from the non-desurfaced plot where no green manure crops were grown or turned under.

WIND EROSION MOST HARMFUL IN EARLY STAGES

Wind erosion has reduced the productive capacity of High Plains wheat lands an average of 2.2 bushels per acre annually on land in continuous wheat culture and 4.29 bushels on land in summer fallow (9). The studies show that erosion during the cultivated life of a field was 4.5 times as destructive in the early stages of erosion as in the later stages. Erosion reduced the yield 0.52 bushels per acre per year for the first 4 years the land was subject to erosion, and at the rate of 0.11 bushels annually for the next 21-year period. Serious erosion began ordinarily 2 to 4 years after the land was first put in cultivation.

Erosion lowered the potential productive capacity of fallow land in line with the annual rate of production loss. As a result, the land capability was affected in such a way as to forecast a step-by-step loss of the productive resources of the High Plains if erosion in this area should continue at substantially the same rate that has prevailed since cultivation began.

A-HORIZON MORE PRODUCTIVE THAN B- AND C-HORIZONS

The A-horizon of naturally eroded Cecil sandy loam produced an average annual acre yield over a 4-year period of 939 pounds of seed cotton compared with a yield of 304 pounds for the B-horizon and 81 pounds for the C-horizon (19). The A-horizon plots produced an average annual yield of 635 pounds more seed cotton per acre than the B-horizon and 858 pounds more than the C-horizon. The A-horizon was more than 3 times as productive as the B-horizon and 11 times as productive as the C-horizon.

Manure was applied at the rate of 4 tons per acre to half of the plots on each horizon in 1939, the last year of the 4-year period of study. The yield of seed cotton as influenced by the addition of the manure is shown in table 8.

TABLE 8.—Effect of the addition of 4 tons of manure per acre on the yield of seed cotton on A-, B-, and C-horizons of Cecil soil

Horizon	Yield of seed cotton per acre	
	Unmanured Pounds	Manured Pounds
A	561	845
B	348	501
C	51	426

The addition of manure resulted in increased yields on all horizons, but its beneficial effect was relatively greater on the C-horizon than on the A- and B-horizons. The addition of manure lifted the yield on the C-horizon plot above that for the unmanured B-horizon plot, but did not raise the yield of the B-horizon plot to that of the unmanured A-horizon plot.

CROP YIELDS HIGHER ON UNERODED THAN ON ERODED SOILS

Experiments conducted over a 4-year period on Fayette silt loam at La Crosse, Wis. and on other soil types at other conservation experiment stations show that crop production was significantly higher on uneroded than on eroded soil (14). Moderately eroded soil with 5 to 6 inches of surface soil yielded significantly more corn, small grain and hay than severely eroded soil which had lost all but 2 inches of its surface soil. This difference in yield was evident even though all plots were brought up to a similar potash and phosphorus level and planted to a 5-year rotation including 3 years of hay. The average yield of corn on moderately eroded soil was 92 bushels per acre as compared with 65 bushels on severely eroded soil. Barley produced 21 bushels per acre on moderately eroded soil as compared with 12 bushels per acre on severely eroded soil. Hay produced 3.5 tons on moderately eroded soil as compared with 3.2 tons on severely eroded soil. The severely eroded soil produced only 70 percent as much corn, 57 percent as much barley and 91 percent as much hay as the moderately eroded soil.

Field tests were made in Wisconsin on 45 farms located as far north as Barron County and as far south as Grant County in order to determine if erosion affected production on other soil types and under other climatic conditions in that State. Slightly eroded, moderately eroded and severely eroded plots were selected in each field where all three stages of erosion were present. At least four plots selected at random were harvested for each soil depth, and on most fields two or three locations of similar soil depth were harvested.

Small-grain yields were obtained on 18 farms of which 15 showed a significantly higher yield on the less severely eroded soil. Three soil depths were found in the same field on 11 farms. Small-grain on these fields yielded an average of 65 bushels per acre where there was 6 or more inches of surface soil, 50 bushels where there was 4 to 6 inches of surface soil and 43 bushels per acre where there was three inches or less of topsoil. In other words, there was a reduction of 22 bushels per acre as a result of the loss of 3 inches of surface soil.

Corn yields were obtained on different soil depths on 12 farms. In each instance the yield of corn was higher on the slightly eroded than on the more severely eroded soil. On 8 of the farms where all the soil depths were present in the same field, the average yield of corn was 80 bushels per acre where the soil was only slightly eroded, 67 bushels per acre where the soil was moderately eroded, and 60 bushels per acre where the soil was severely eroded.

These data indicate that the yield of a crop is significantly decreased with loss of topsoil through erosion, and that depth of surface soil is a major factor influencing yields of crops. With few exceptions, the yield was correlated directly with the depth of surface soil regardless of soil type, variety of crop, cultural treatment, fertilizer practice or climatic condition.

A study was conducted in Wisconsin over the 6-year period 1939-44, using 45 farms classified on the basis of their susceptibility to erosion losses (2). It was found that the shallower the topsoil, the smaller was the yield of crops. In general, the greater the erosion hazard on a given soil type, the less was the amount of topsoil remaining. Crop yields of the farms with the greatest probability of losing their surface soil were as low as 89 percent of the average for all farms, whereas for the farms with the least probability the yields were as high as 109 percent of the all-farm average.

The records show that the differences in corn and oat yields among these groups of farms were highly significant. The differences in hay yields were somewhat smaller. The reduction of yield on the fields with the greater erosion hazards was only about 1/7 for hay in comparison with a reduction of from 1/4 to 1/3 for the small grain and corn crops. The indexes of crop yields of farm lands with different erosion hazards for the 6-year period of study are recorded in table 9.

TABLE 9.--Index of crop yields of farm lands with different erosion hazards

Erosion hazard	Yield index, all crops	Yields			
		Corn	Oats	Hay	Silage
		Bu. per acre	Bu. per acre	Tons per acre	Tons per acre
A (least)	109	63	48	2.2	10.0
B	103	61	41	2.1	10.1
C	99	60	43	1.9	9.1
D (greatest)	89	49	34	1.9	8.0

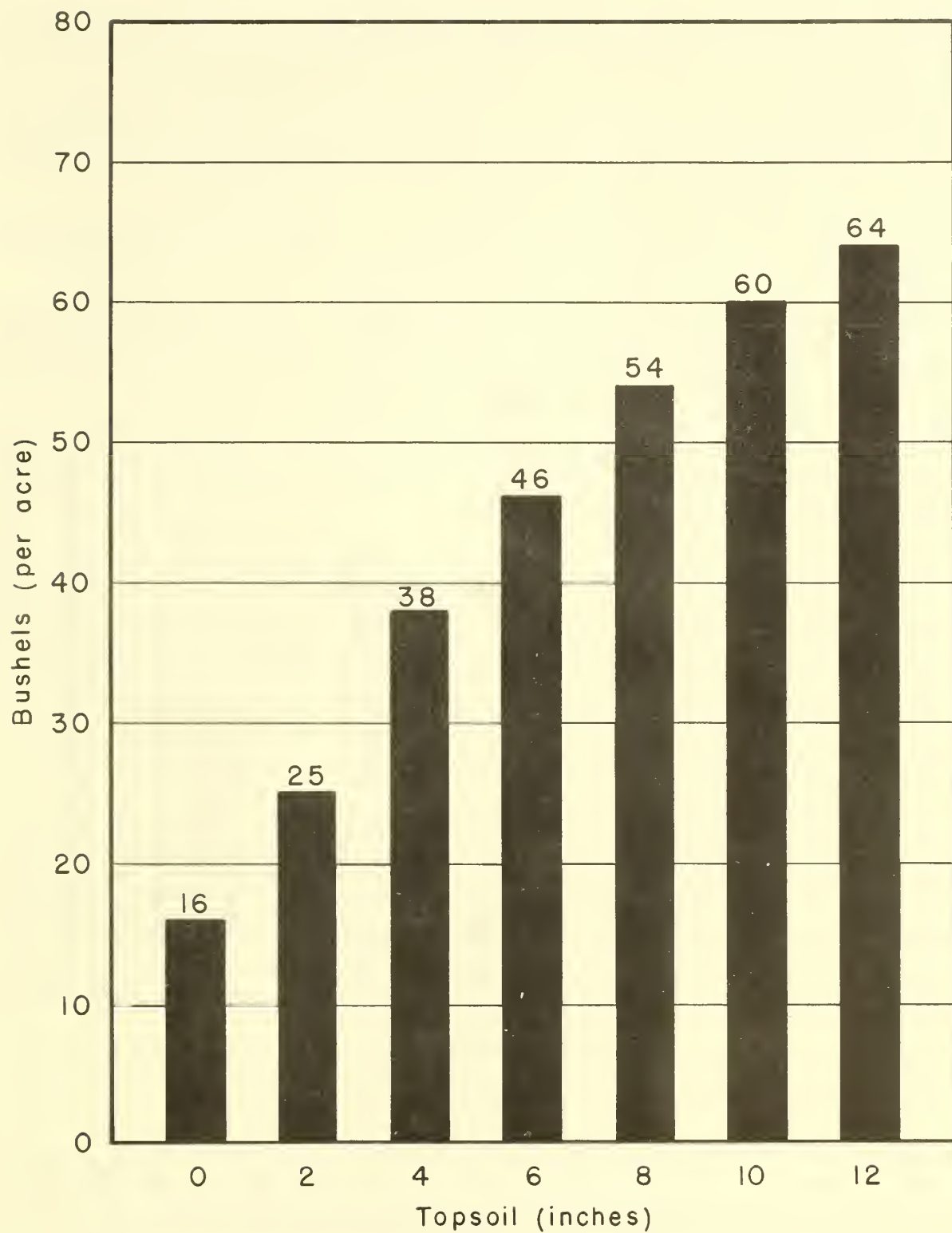


Figure 9.-- Average annual yield of corn in bushels per acre on Shelby, Grundy and Mexico soils as influenced by the depth of topsoil, 1940-44.

The average annual acre yield of corn on certain soils in Missouri declined from 64 bushels with 12 inches of topsoil to 16 bushels where all the topsoil had been eroded away (32). Yields were obtained on Shelby, Grundy and Mexico soils over the 5-year period 1940-44 on soils with 0, 2, 4, 6, 8, 10, and 12 inches of topsoil. The average annual acre yields in bushels for the three soil types studied were 16 bushels where topsoil was lacking, 25 for 2 inches of topsoil, 38 for 4 inches of topsoil, 46 for 6 inches of topsoil, 54 for 8 inches of topsoil, 60 for 10 inches of topsoil and 64 bushels per acre for 12 inches of topsoil. These yields are shown in figure 9. Past erosion reduced the yield of soybeans on an average of about 1.79 bushels per acre per inch of topsoil lost on Shelby soil and 0.73 bushel on Marshall soil.

Data secured in 1938 by the technical staff of the Greenfield, Iowa Soil Conservation Service demonstration project showed that the average corn yield was lowered about 5 bushels per acre for each inch that the surface soil was lowered below 8 inches by erosion (35).

The yield of corn in 1939 at Bethany, Mo. ranged from 17.1 bushels per acre where only 3 inches of topsoil remained to 47.3 bushels where 13 or more inches of topsoil remained (37). These were the average yields of four fields where yields were determined for different depths of topsoil in the same field. A similar study of seven fields during 1940 showed a corn yield of 15.2 bushels per acre where all the topsoil had been removed by erosion as compared with a yield of 67.5 bushels per acre where 13 or more inches of topsoil remained.

Both of these studies showed that there was a constant and substantial decline in corn yield with the loss of each inch of topsoil. The yields are shown graphically in figure 10. The data for 1939 show the yield for each inch of topsoil depth from 3 inches through 13 inches, and those during 1940 show the yield for each 2-inch depth.

Similar studies were conducted during 1939 and 1940 in Indiana, Iowa and Ohio. In the studies carried out near Fowler, Ind., as at Bethany, Mo. the corn yields were determined for different soil depths in the same field. The studies were made on 16 fields in 1939 and on 18 in 1940. The depth-classes of topsoil ranged from 1 to 13 inches in 1939 and from 0 to 13+ inches in 1940. There was a consistent decline in the yield of corn for each inch of topsoil lost. The average yield for the 16 fields in 1939 ranged from 49.2 bushels per acre for topsoil 1 to 2 inches deep, to 93.4 bushels for the 13+ inch depth. The corresponding yields for the 18 fields in 1940 ranged from 19.8 bushels per acre where all the topsoil had been removed by erosion to 69.5 bushels where 13+ inches of topsoil still remained. In 1939, the 1- to 2-inch depth of topsoil produced only 52.6 percent as much corn as did the soil that was 13 inches or more in depth. In 1940, land without topsoil produced only 28.4 percent as much as did the soil that was 13 inches or more in depth. These yields are shown graphically in figure 11.

The 1939 yield data for each of the three important soil types mapped in the 16 fields at Fowler are presented graphically in figure 12. The data show that for comparable depths the corn yields for the three soil types were fairly consistent, except for the 11.5- and 13.5-inch depths of the Parr silt loam. However, in general there was a substantial decline in the corn yield on each soil as the depth of topsoil decreased. The Fowler silt loam averaged 51.9 bushels of corn per acre on areas where the topsoil was from 3 to 4 inches deep compared with 92.9 bushels for areas having 13 inches or more of topsoil remaining. Similarly, the Parr silt loam produced an average of 49.2 bushels of corn per acre where the topsoil averaged 1 to 2 inches in depth and 112.5 bushels where the topsoil was 13 or more inches deep. Corresponding yields for Brookston silt loam were 50.6 bushels per acre where the topsoil was 3 to 4 inches in depth and 92.4 bushels where there was 13 or more inches of topsoil.

The 13+ inches of topsoil produced 1.78 times as much corn as the 3- to 4-inch depth of topsoil on the Fowler silt loam, 1.82 times as much on the Brookston silt loam, and 2.28 times as much as the 1- to 2-inch depth on the Parr silt loam.

Corn yields obtained on two soil types at Greenfield, Iowa in 1938 and on 10 fields at Shenandoah, Iowa in 1939 also showed a consistent relation between depth of topsoil and corn yield. The Tama silt loam produced 31.8 bushels of corn per acre where the depth of topsoil was 0 to 2 inches compared with 63.9 bushels with 11 to 12 inches of topsoil. Corresponding yields for the Shelby silt loam were 24.7 bushels per acre on the 0 to 2 inches of topsoil and 49.8 bushels for the 9- to 10-inch depth of topsoil. The average yield for the 10 fields at Shenandoah was 52.3 bushels per acre for the 1- to 2-inch depth of topsoil and 119.9 bushels for the 11- to 12-inch depth. The results of the study conducted at Shenandoah are shown graphically in figure 8.

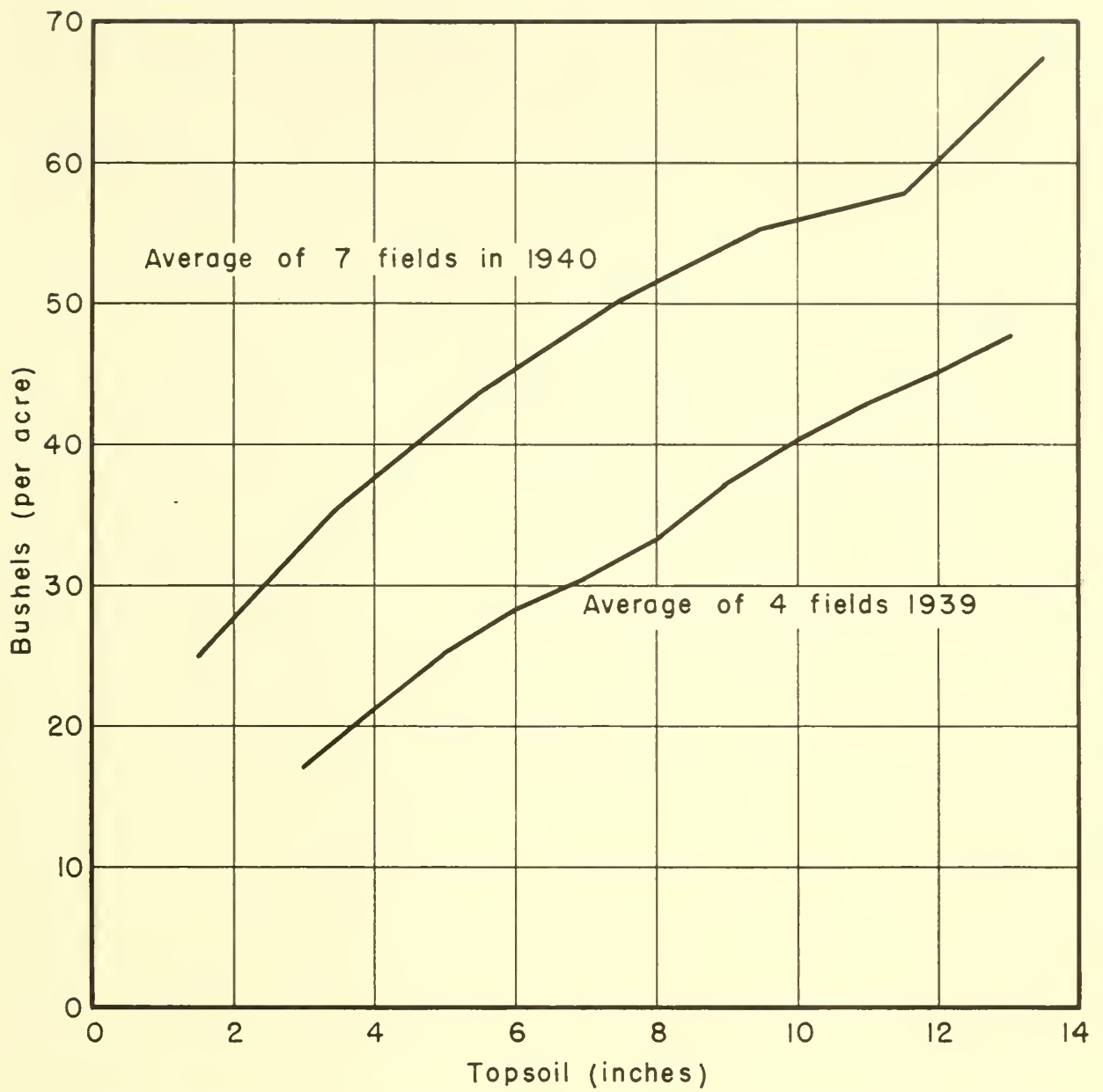


Figure.10.-- The average yield of corn per acre for different depths of topsoil at Bethany, Missouri in 1939 and 1940.

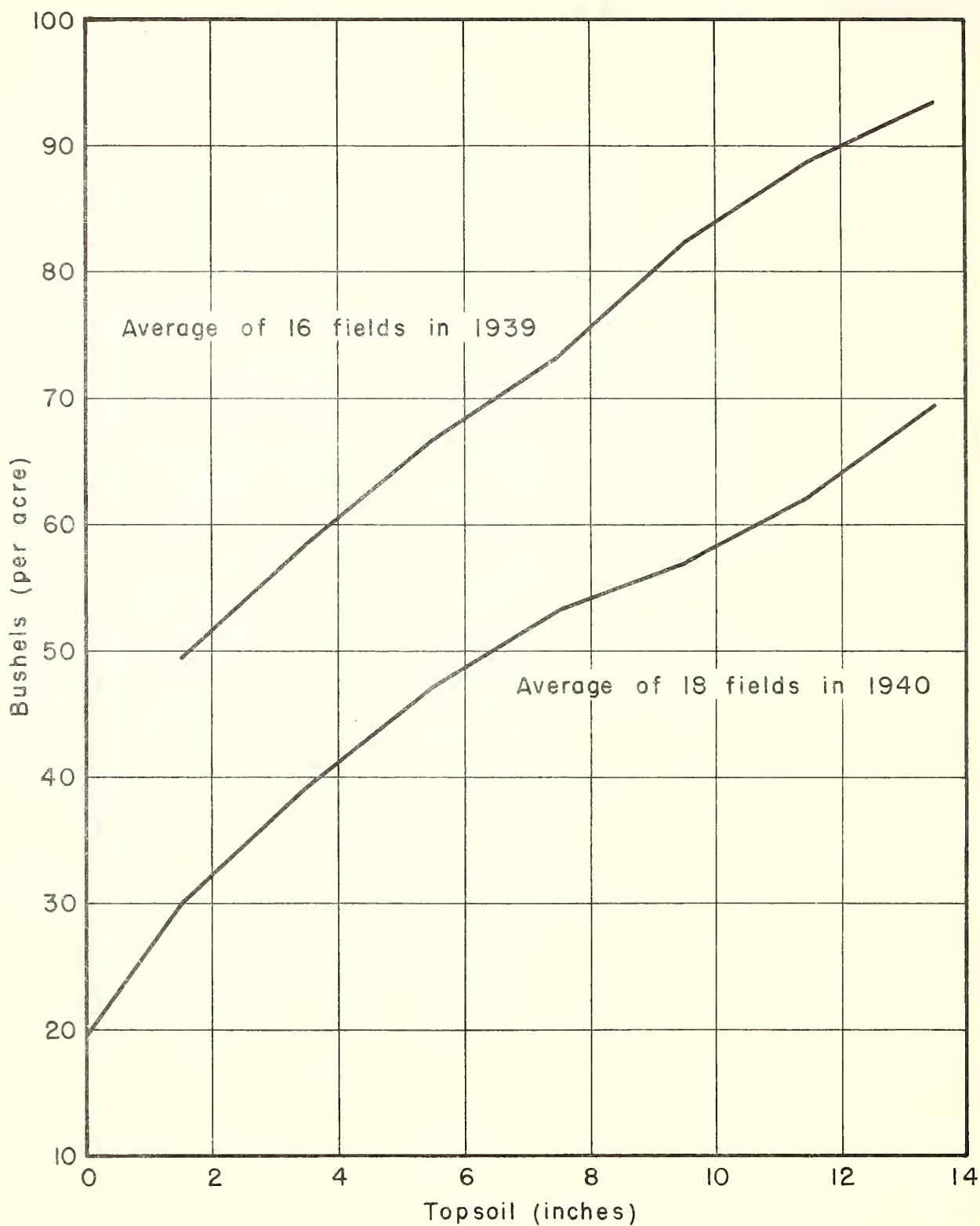


Figure 11.-- The average yield of corn in bushels per acre for different depths of topsoil near Fowler, Indiana in 1939 and 1940.

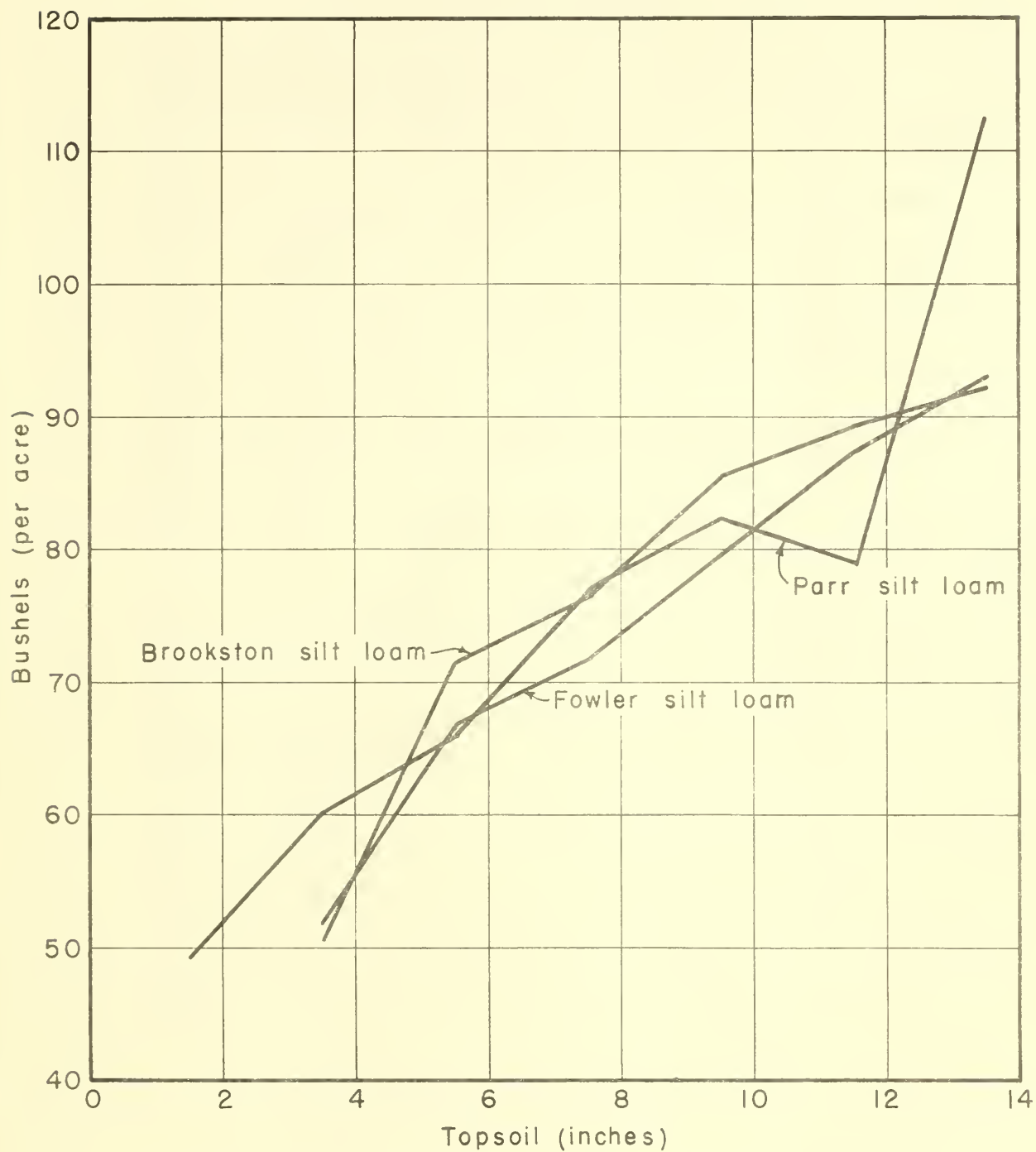


Figure 12.-- Corn yields expressed in bushels per acre for different depths of topsoil for three soil types near Fowler, Indiana, in 1939.

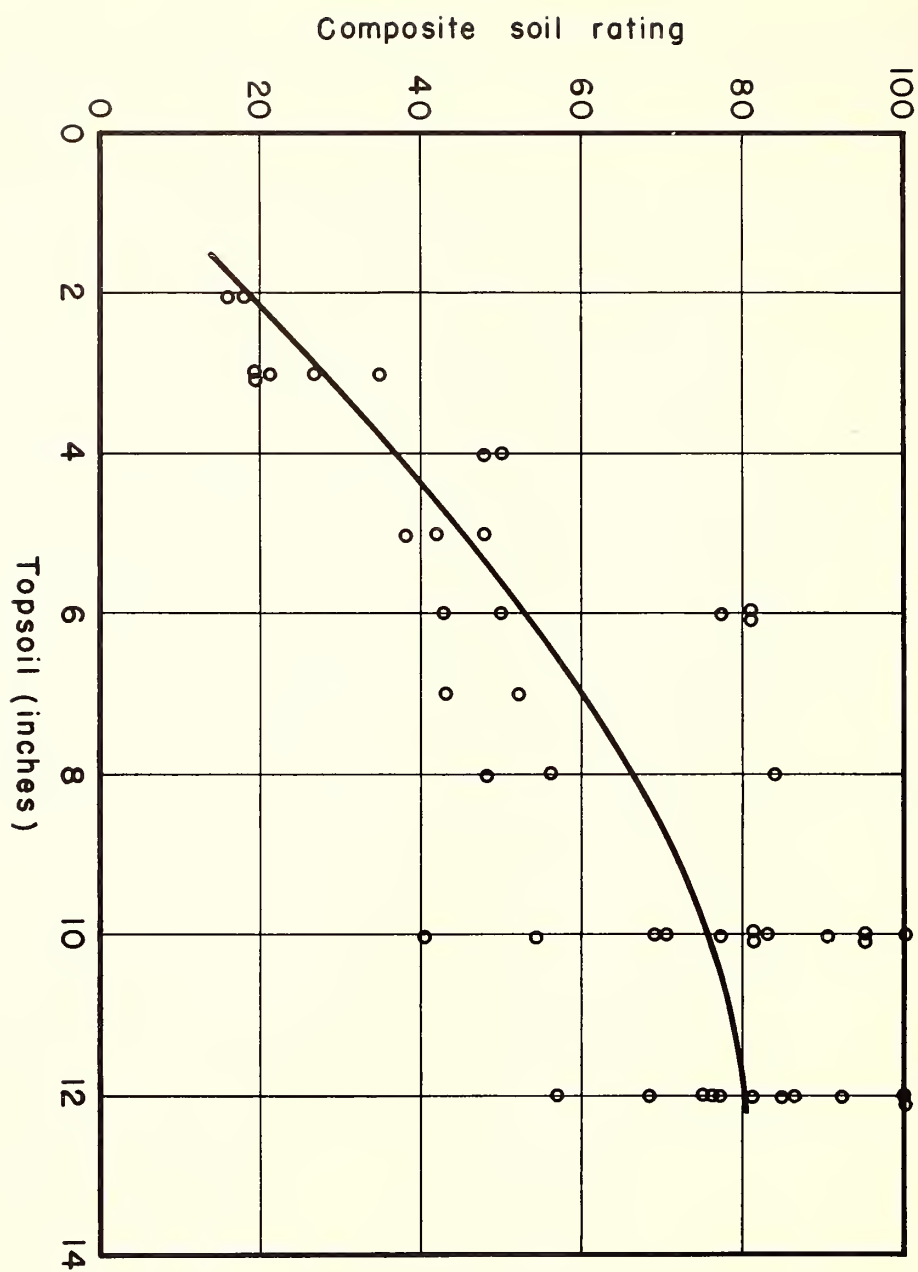


Figure 13.-- Composite soil rating vs. depth of topsoil, Geary County, Kansas.

Approximate evaluations of the principal soil characteristics such as profile, surface texture, slope and erosion were made for the soils of Smokey Hill and Lyon townships of Geary County, Kans., (26). These evaluations were tested and revised by the use of crop-yield data collected by two methods: (a) a survey of farms to obtain yield and practice data for fields of small grains, and (b) harvesting samples of corn from the different soils in fields farmed by the same operator under identical cultural practices.

The results of this evaluation showed that productivity was inversely proportional to the degree of erosion. The productivity rating ranged from 95 percent for none or slight erosion to a minimum of 40 percent for very severe erosion, whereas moderate erosion had a rating of 85 percent and severe erosion 70 percent.

It is of interest to consider the composite soil rating in relation to depth of topsoil alone. This relationship for the 46 samples comprising the basic data is shown in figure 13. It will be noted that on the average the composite soil rating is about 20 for a topsoil depth of 2 inches. Where the depth of topsoil is 12 inches the average composite soil rating averages approximately 80, or four times as great.

The basic data on corn yields from the upland soils in the study indicated that in 1936 the yields averaged about 38 bushels per acre where the topsoil depth was in excess of 6 inches. An average decrease in yield of approximately 3.5 bushels per acre appeared to be associated with a loss of each inch of topsoil after the 6-inch level was reached.

Yields of wheat for 1946, as calculated from the yield and practice survey in Geary County, Kans. are shown in table 10.

TABLE 10.--Effect of erosion on the yield of wheat in Geary County, Kansas, 1946

Topography and degree of erosion	Yield
	Bu. per acre
Level to gently sloping - none to slight erosion	21
Undulating to sloping - none to slight erosion	18
do - severe erosion	11
do - very severe erosion	8

In Yates County, N. Y., moderately eroded soil produced three times as many grapes as severely eroded soil, and slightly eroded soil produced five times as many (13). The slightly eroded soil averaged 14 inches in depth, the moderately eroded 11 inches, and the severely eroded 5 inches.

The yields of both corn and cabbage were higher on uneroded Dunkirk soil at Geneva, N. Y. in 1943 than on severely eroded soil of the same type despite the fact that 126 pounds of readily available nitrogen was applied per acre to the severely eroded soil and none was applied to the slightly eroded soil. The uneroded soil produced 4.7 tons of sweet corn and 16.7 tons of cabbage per acre in contrast with yields of 3.2 tons of sweet corn and 13.8 tons of cabbage per acre for the severely eroded soil.

Moderately eroded soil (33 inches of soil over shale) in Ontario County, N. Y. produced 38 No. 1 rose stock per hundred feet of row space, whereas severely eroded soil (14 inches of soil over shale) of the same type and in the same field produced none. The moderately eroded soil produced 18 No. 1 1/2 grade stock per hundred feet of row space against 4 for the severely eroded soil, and 11 No. 2 grade rose stock as compared with 34 for the severely eroded soil. The detrimental effect of erosion on the yield of rose stock is accentuated by the low commercial value of the No. 2 rose stock.

Yields of oats were obtained on five widely scattered farms in southeastern Minnesota from areas that were as nearly uniform as possible with the exception of depth of topsoil (15). Slightly eroded or uneroded, moderately eroded, and severely eroded plots were selected in each field. The yield of oats on uneroded soil with 10 or more inches of surface soil was 36.1 bushels per acre. The yield on moderately eroded soils, with 5 to 10 inches of surface soil remaining, was 30.0 bushels; and the yield on severely eroded soils, with 5 or less inches of surface soil remaining, was 22.7 bushels per acre. In other words, the uneroded soil produced 6.1 bushels more oats per acre than the moderately eroded soil, and 13.4 bushels more per acre than the

severely eroded; and the moderately eroded soil produced 7.3 bushels more per acre than the severely eroded soil. Yield data obtained on Bellefontaine silt loam during 1944 from 10 farms with severe and moderate erosion and from 3 farms with slight erosion show an average yield of 92.8 bushels of oats per acre for slight erosion, 74.6 bushels for moderate erosion and 66.8 bushels for severe erosion.

Wheat yields on the South Fork of the Palouse Project in Washington ranged from 15.3 bushels per acre where all the topsoil had been removed by erosion to 50 bushels where an average of 24 inches of topsoil remained (17). The yield was 35.1 bushels of wheat per acre where the topsoil depth averaged 10.7 inches and 22.7 bushels for an average topsoil depth of 4.7 inches. These yields were all on land with a south slope and represent the average for a number of sites over a 3-year period. Corresponding yields for land with a north slope were 18.5 bushels of wheat per acre where the topsoil averaged 18.5 inches in depth as compared with 42.6 bushels where the topsoil depth averaged 27.4 inches. The data are shown graphically in figure 14.

Runoff plots were established at Pullman, Wash. in 1935 on a tract of newly cultivated virgin land and on adjacent land that had been under cultivation for about 50 years. The old cultivated land had lost about one-third of the original topsoil by 1934. A cropping system consisting of winter wheat grown in alternate years with summer fallow was initiated on both sites in 1934. The average annual yield per acre for the 11-year period, 1936-46, was 38.7 bushels for the virgin land put in cultivation in 1935 and 22.8 bushels for the land that had been put in cultivation some 50 years or more earlier. In other words, the productive capacity of the land put in cultivation about 1885 had declined 15.9 bushels. This decline in production averaged about 0.33 bushel per acre annually over the 50-year period.

In New Jersey, yields of nine crops were measured over varying periods of time on areas with less than 6 inches of topsoil and on other areas with more than 6 inches to determine the relation between yields and the depth of topsoil (25). There was a significant difference in yields in every case in favor of the greater depth of topsoil. The results are shown in table 11.

TABLE 11.--Crop yields per acre for various depths of topsoil, New Jersey

Crop	Average number locations studied	Years of study	Depth of topsoil	
			0 to 6 inches	6 inches or more
Potatoes	12	7	233 bushels	298 bushels
Corn	4	5	40 do	64 do
Wheat	4	5	17 do	34 do
Oats	2	3	21 do	32 do
Soybeans	2	3	4 do	18 do
Barley	2	3	26 do	55 do
Rye	2	3	11 do	37 do
Alfalfa	2	3	2 tons	3.3 tons
Asparagus	1	1	232 pounds	728 pounds

Studies conducted during each of 8 years with corn, soybeans, oats, rye, barley and alfalfa in New Jersey (28) showed that where all factors other than erosion were constant, the yields of all of these crops from eroded areas were less than those from comparatively uneroded areas. Data collected during 1948 for wheat and potatoes show the same results. Wheat yields from eroded areas averaged 25 bushels per acre in contrast with 46 bushels for uneroded areas in the same fields. Differences in potato yields were even greater. Eroded areas averaged 124 bushels while uneroded portions of the same fields averaged 383 bushels per acre.

TERRACING AFFECTS YIELDS

Corn yields at Bethany, Mo. were affected by the unequal distribution of the mantle of topsoil as a result of field terracing (39). Using the yield obtained on the top of the terrace ridge as a basis of comparison, the yield increased to a maximum at a point just off the terrace back-slope, or approximately 15 feet down the slope from the ridge center. It declined progressively from this point down the slope to the center of the terrace channel. The yield increased from the channel to a point approximately one-half the distance to the ridge top of the front slope of the terrace berm. It again showed a decline where the surface soil on the remainder of the front slope of the terrace was more than 1 foot deep.

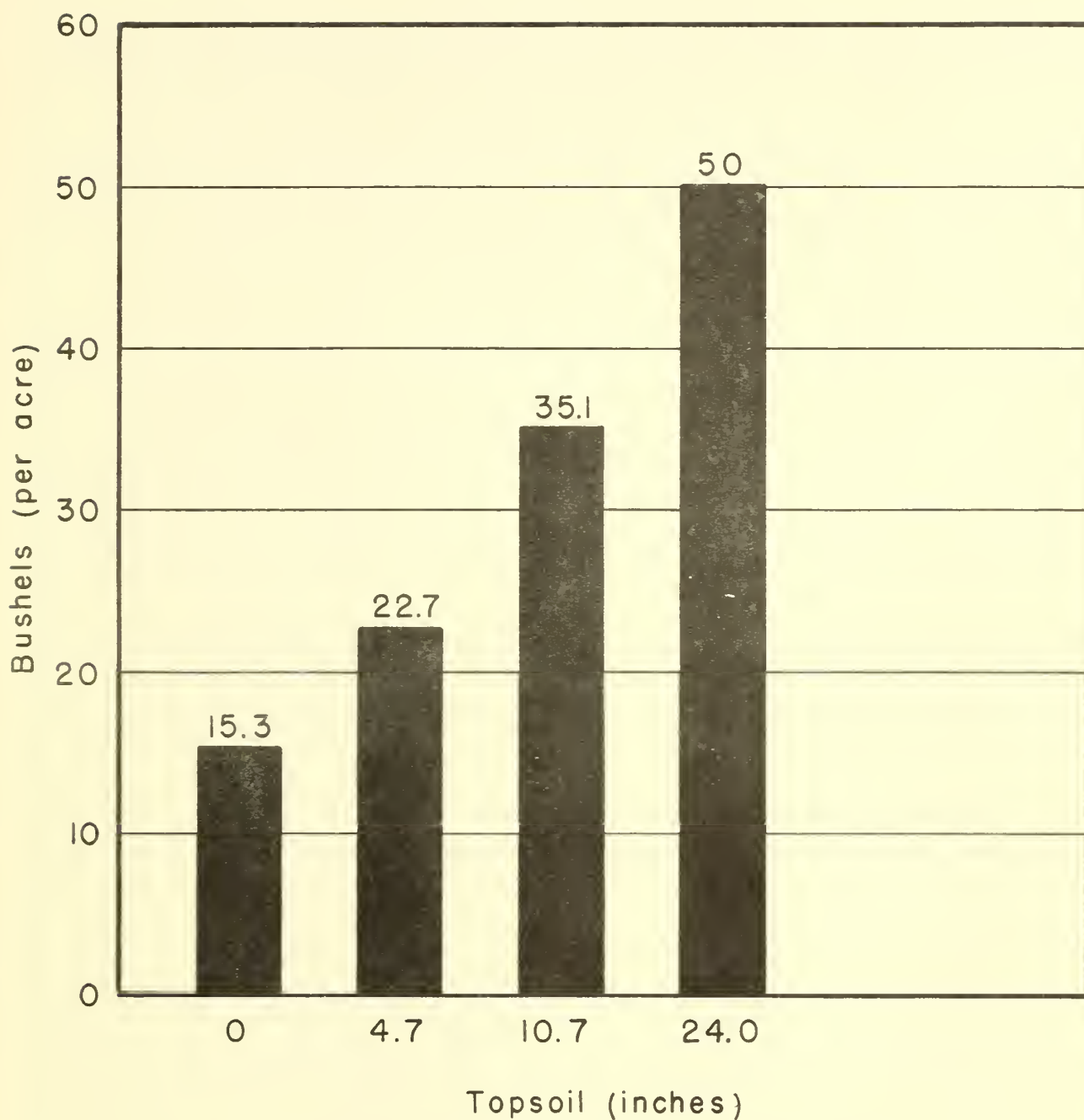


Figure 14.-- Wheat yields correlated with the depth of topsoil, South Fork, Palouse Demonstration Project. 1936-39.

The yield of corn increased with depth of surface soil, regardless of its location on the terrace, to surface soil depths up to 1 foot. Soil depths above this figure occur on the terrace ridge, and a slight decline in yield occurred on these extra depths of filled-in surface soil.

CROP YIELDS HIGHER ON TOPSOIL THAN ON SUBSOIL

A study was initiated in 1936 near Wooster, Ohio to determine the relative crop production of topsoil and subsoil (37). Three series of plots were used. The topsoil was stripped off down to the subsoil on one series of plots. This topsoil was spread over a second series of plots where the original topsoil was undisturbed, thus doubling the depth of topsoil. On a third series of plots the original topsoil was left undisturbed. Corresponding plots in each of the three series were planted to the same rotations and given identical treatment otherwise.

The average annual yield of corn, oats, wheat and hay per acre on these plots for all treatments for the 9-year period 1937-45 are shown in table 12.

TABLE 12.--Effect of depth of topsoil on the yield of corn, oats, wheat and hay at Wooster, Ohio over a 9-year period

Crop		Average annual plot yield		
		Double topsoil	Virgin topsoil	Subsoil
Corn	bushels	98.65	81.82	39.31
Oats	do	52.13	57.24	21.37
Wheat	do ¹	33.2	27.9	11.8
Hay	tons	3.67	2.60	1.94

¹Average for 1937-47.

The yield of each kind of crop except oats was higher on the double topsoil than on the virgin topsoil. For oats, the average annual yield was some 5 bushels per acre higher on the virgin-topsoil plots than on the double-topsoil plots. The yields were much lower in every case on the subsoil plots than on the virgin-topsoil plots. On the subsoil the corn yield was only 48 percent of that for the virgin topsoil. Corresponding percentages for the other crops were 37 for oats, 42 for wheat and 74 for hay.

Untreated soil from which about one-half the topsoil had been removed by erosion yielded more than four times as much grain as untreated subsoil at Bethany, Mo. over a 7-year period (37). Similar soils limed at the rate of 3 tons per acre in the beginning and fertilized with 200 pounds of superphosphate per acre produced 1.8 times as much grain where one-half of the topsoil still remained as the subsoil that received the same treatment. The addition of 8 tons of manure per acre in addition to the fertilizer produced 1.82 times as much corn on the area which had about one-half of the topsoil remaining as was produced on the subsoil.

A study similar to that reported at Wooster was started at Columbus, Ohio in 1938. The average annual acre yield of corn for all treatments in the three series of plots for the 8-year period 1938-45 was 42.9 bushels for normal topsoil, 18.2 bushels for subsoil and 67.0 bushels for the double topsoil. The addition of 500 pounds of 0-14-6 fertilizer per acre and enough limestone to bring the pH to 6.5 changed the yields to 48 bushels per acre for normal topsoil, 20.1 for subsoil and 65.2 for double topsoil.

A study was made in California of the influence of soil horizons A, B, and C on the rate of growth of certain annual plants which dominate early successional stages, compared with certain perennial herbs recognized as stable or climax in grassland communities, and on the comparative plant development in horizons A, B, and C (29).

The growth rate of both the annual and the perennial species was appreciably greater in horizon A than in lower horizons, regardless of the soil series or the species used. Likewise, the amount of plant material produced in horizon A was consistently greater than in horizon C, regardless of species or soil series. This held true, also, in horizon B with the exception of Olympic soil, in which the B-horizon proved nearly as productive as the A-horizon for two annual species. This deviation from the average trend may be accounted for by the fact that the soil used to represent the Olympic series was produced in grassland formation; hence, the B-horizon may have been subject to greater accumulation of materials from the upper horizon than in the forest soil.

These studies indicate the importance of keeping intact the A-horizon soil layer, which according to preliminary studies of nutrient displacement, is richer in both total nitrogen and nitrate nitrogen than the underlying horizons. The removal of the A-horizon tends not only to decrease the luxuriance of growth of the vegetation but to greatly retard, if not actually prevent, the reestablishment of the climax and subclimax plant cover.

Greenhouse studies of lettuce grown in topsoils and subsoils of some of the prevalent soil types in California gave irrefutable evidence that the topsoils consistently out-yielded the subsoils (6).

EROSION REDUCES EFFICIENCY OF FERTILIZERS

Studies in New York showed that cropping and cultural practices that resulted in sheet erosion rapidly led to inefficient use of fertilizer (18). Corn was grown on four of the leading soil types of the State which were cropped uniformly and fertilized with 1,000 pounds of 10-10-10 fertilizer per acre. The per-acre yields ranged from 17 to 88 bushels on Bath flaggy silt loam at Ithaca; 62 to 100 bushels and 54 to 82 bushels, respectively, on Ontario sandy clay loam and Dunkirk silty clay loam at Geneva; and from 49 to 69 bushels on Honeoye silt loam at Marcellus even after two years of alfalfa-clover-timothy hay.

Along with the decline of productivity chargeable to removal of soil by erosion has gone a lesser but more steady decline of fertility from the land due to crop removals. The decline of productivity in the Southern High Plains due to erosion was five times as great as that due to crop removals during the first 4 years of cultivation (9). It was only 1.5 times as great during the next 21 years of cultivation. The total decline in productivity of land that had been in cultivation 15 years or more, due to both causes, amounted to 7.01 bushels of wheat per acre.

CONCLUSION

Soil erosion has played, and continues to play, a major role in destroying the productive capacity of the Nation's soil. In fact, the erosion process is now recognized as the most widespread and destructive agent involved in bringing about the rapid depletion of the fertility and productive capacity of cultivated land. This is accomplished through the removal of the organic matter, nitrogen, and clay and silt fractions, which are the life of the soil, as well as through the physical removal of the soil body itself.

The selective and sorting action of wind and water in the erosion process under some conditions may remove organic matter and essential plant nutrients without producing a significant net loss of soil from the surface of the land. This process leaves the soil in an infertile state. In order to restore the soil to its original state of fertility the plant nutrients and organic matter thus removed must be replenished. This, if physically possible of accomplishment, would involve tremendous expense. In many instances, replacing the lost material would be completely out of the question.

Wind and water action in its most violent forms not only results in the loss of the plant nutrients and organic matter but in the physical removal of the soil mass. This is important since on most soils the thickness of the surface soil, or A-horizon, determines the amount and quality of growing space available for root development for most cultivated crops. This in turn determines the potentialities of the remaining soil for crop production.

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